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THE IMPORTANCE AND OBJECTIVES OF MAINTENANCE ENGINEERING

by

D. Parkes
British Council of Maintenance Associations
United Kingdom

Organized in co-operation with the German Foundation for Developing Countries and the German Association of Machinery Manufacturers (VDMA).

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PART I: INTRODUCTION

Maintenance engineering is that branch of engineering concerned with the upkeep of plant, machinery and equipment of all kinds and of particular significance in the process and manufacturing industries. But engineering technology is not solely involved - many of the arguments for better maintenance relate to economics, safety or expediency and these are matters of 'management' concern.

For industrial enterprises the most attractive advantage of better maintenance is that it can save money and lead to greater productivity. This is the case for all types of enterprise, state-controlled, co-operative, or privately run. It is also equally true for enterprises engaged in manufacturing or processing or providing a service (transport, for example).

(a) Terminology

One of the problems facing an international symposium on this subject is that the word 'maintenance' has no internationally agreed definition. There are, however, some national definitions which have become widely accepted. In the United Kingdom there is indeed an 'official' national glossary of maintenance terms*. This defines maintenance as "work undertaken in order to keep or restore every facility, that is every part of a site, building and contents, to an acceptable standard". It will be seen that this definition includes preventive action carried out 'to keep' things in good order and also includes corrective action carried out 'to restore' things to the selected acceptable standard. Although much of this British Standard has been adopted elsewhere it is felt within certain of the United Nations agencies that there is merit in continuing the older usage of the two separate words 'repairs' and 'maintenance'.

In some languages the distinction is even more pronounced. For example, in Polish, the activities connected with maintenance are 'konserwacy' which means 'upkeep' and 'remont' which means 'repairs'.

* British Standard 3811: 1964 Glossary of general terms used in maintenance organization.

In Dutch the word 'onderhout' is used very widely as the equivalent of 'maintenance' even though, as in English, there is a separate word ('reparatie') for 'repairs'. A Dutch definition of 'onderhout' is keeping in good condition: the preservation of a desired degree of working order or readiness for use. An interesting linquistic sidelight is that the motto on the Dutch Coat of Arms for the past 400 years has been 'Je Maintiendrai' or 'I shall preserve'.

The German word 'instandhaltung', the French word 'entretien', the Italian word 'manutenzione' are all broadly equivalent to 'maintenance' although each language has separate words which are sometimes used for 'repairs'.

Within the Socialist bloc work has been going on for some years to create better understanding about the language of maintenance. It was found that, even within the participating countries of Czechoslavakia, German Democratic Republic, Hungary and Poland, there were some maintenance terms which had completely opposite meanings. So the Polish Association of Engineers and Mechanics (SIMP) took the initiative in compiling a five language dictionary of maintenance terms with definitions according to Polish specifications. They expressed the hope that other countries would eventually undertake or complete similar work in preparation for a truly international standard of terms.

Although some international progress is being made on maintenance terminology it is too early to forecast the outcome of the discussions. One unilateral development on terminology has come recently from the United Kingdom. A working party had carefully studied the national maintenance scene and had found that even in that industrially developed country there were enterprises which paid insufficient attention to the maintenance of their plant and equipment. It was then suggested that there might be a psychological advantage in the introduction of a new word to cover the broad aspects of maintenance which are being discussed here - but which are apparently not always meant by people when the word maintenance is quoted. The new word was developed from a classical Greek word 'tereo' which means 'to care for, to watch over'. So the English language has a new word 'terotechnology' which covers not only the ordinary aspects of maintenance but also installation, commissioning, replacement and removal of plant and equipment together with feedback from maintenance to design "and related subjects and practices".

For the present symposium there is, perhaps a danger of becoming too obsessed with the finer points of word meanings. What is important, however, is the recognition that properly planned maintenance must include provision for preventive work.

In considering the importance and objectives of maintenance all kinds of maintenance and repair work will be included. It should be remembered also that relative importance of the objectives mentioned will vary with the circumstances. Throughout this paper the significance of the local circumstances will be apparent; because of this no attempt has been made to set down precise 'rules'. Indeed the intention is to provide guide lines to thinking rather than ready-made answers to problems.

PART II: THE EXECUTION OF MAINTENANCE

(a) Prolonging useful life

One objective of maintenance is to extend the useful life of a machine or piece of equipment. This is possibly the most widely accepted reason for carrying out maintenance but it is especially important where the equipment is very expensive or difficult to obtain. It may be particularly significant where there is a shortage of a certain kind of currency. In this special case the cost of maintaining the equipment might become substantially higher than the cost of replacing it; the maintenance costs can, however, be paid in local currency.

Although it is often possible to obtain locally-made replacement parts it is unfortunately still true that in some cases these prove to be less than completely satisfactory. This was a situation reported from a number of countries when the UN Centre for Industrial Development held a two-weeks meeting of maintenance experts in New York towards the end of 1966. The reports indicated that the shortcomings usually concerned quality, accuracy, durability or surface finish. The reasons for these shortcomings appear to be shortage of appropriate materials or lack of adequate foundry or heat treatment facilities.

Prolonging the useful life of equipment may therefore be extremely important. To deal with this it is necessary to look at the causes of wear and deterioration. One generalization is possible: keeping the equipment clean can sometimes prove the most effective single factor in reducing the effects of wear and deterioration. It is not unusual for the responsibility for the cleaning of equipment to be placed primarily on the person operating it, but it must remain the concern of the maintenance department that the cleaning has been carried out. In any case there will be some aspects of machinery cleaning which must remain the responsibility of the maintenance staff if only because of possible hazards of which the maintenance staff should be aware. (See later section on 'keeping things safe').

Although cleanliness is always important for prolonging useful life, it is obviously most vital where the contaminant is abrasive (like cement), corrosive (like chemicals, sugar or fruit juices), or has an explosion hazard (very fine dusts).

Lubrication is vital for all equipment with moving parts. The application of the right quantity of the right lubricant at the right frequency can contribute greatly to the reduction of wear. In many ways the planning of regular lubrication is both the simplest and the most rewarding maintenance activity. It is therefore surprising to find that, in some countries, it is not yet carried out effectively.

There is a great deal of information available on lubrication practice and all the international oil companies will provide advice and help both liberally and freely. The correct choice of oil or grease or other lubricant can not only prolong useful life for the equipment but minimize the cost of both lubricant and its application.

Proper training is essential for the maintenance men responsible for the application of the lubricants. This task has sometimes been regarded as one not requiring skill but better maintenance standards demand better trained lubrication personnel.

Cleaning and lubrication alone are not sufficent to prolong useful life. It is equally important that the equipment should be kept in accurate adjustment. Unnecessary wear can rapidly occur when attention is not paid to this.

In attempting to prolong useful life many steps are taken to reduce the effects of corrosion and wear. Cleaning and lubrication have been specifically mentioned but attention to these alone is not sufficient. It is important, for example, that moving parts should be kept in accurate adjustment. It is equally important in some circumstances that the provisions made by the designer for the resistance to corrosion and wear continue to be effective. Some equipment may be make use of an impervious coating to protect vulnerable parts from attack by corrosive fluids; such a coating needs to be maintained in good order. Some equipment may have expensive components protected against wear by the presence of renewable inexpensive 'wearing plates'; clearly it is essential that these should be replaced before they become ineffective.

Much of the work discussed above forms part of a preventive maintenance programme. There is still room for improvement despite the progress which has taken place in some countries within the past few years. The United Nations experts reported that only about a quarter of the replies they had received in

their survey disclosed that "either they themselves practised preventive maintenance, or that it was a generally accepted procedure in their countries. The majority of the enterprises that reported following regular lubrication, cleaning, resharpening etc., practices were large industrial enterprises which were either subsidiaries of foreign companies, or government establishments".

There is still room for improvement despite the progress which has been apparent in some countries since that report.

(b) Optimizing availability for use

Under the objective of 'prolonging useful life' an attempt has been made to examine the importance of preserving the value of the equipment. Even though the equipment may be well preserved, however, it will serve little useful purpose if it is not available for productive use when it is so required.

It is this objective - that of optimizing availability for use - which underlines the importance of better maintenance management. The right amount of maintenance has to be carried out at the right time on the right items of equipment. Not all items will demand the same amount of attention; and decision-making, planning and scheduling will need most careful attention if the objective is to be achieved. It should be noted that availability is not necessarily being maximized. There is an economic limit to the availability of equipment.

In the more complex manufacturing or process industries the equipment may require extensive and almost continuous attention and so the direct costs of maintenance may be high. (The direct costs being maintenance department labour, materials and overheads). But in industries such as these there may be substantial monetary losses if the equipment breaks down or is for some reason not available for production. The situation calls for careful assessment of the right amount of maintenance. Too little will mean heavy costs of lost production (often referred to as 'indirect maintenance costs'); too much maintenance will mean that the direct maintenance costs become unnecessarily high.

Generally speaking, the higher the degree of availability demanded, the higher will be the cost of achieving this in terms of preventive maintenance and the provision of stand-by equipment or replacement units. Such increasing costs must be set against the increasing value of output from the equipment.

It is usually possible to establish an optimum target of availability. (See figure 1).

There are some special problems concerning equipment availability. Some production or processing work is seasonal in character, for example, food canning or sugar beet processing. The objective here would be to keep the equipment available for long continuous periods at a certain time of the year and then to carry out necessary - and possibly extensive - maintenance work when it is not required for use. Similar seasonal characteristics apply to electrical power generating plant in countries having a large variation in climatic temperature throughout the year. During the warmer periods advantage is taken to overhaul the equipment so that it can be operated for long periods during the winter.

(c) Readiness for use

One of the most important objectives of maintenance in some circumstances may be to keep the equipment in a state of readiness for instant and efficient use in case of emergency. Examples include the equipment in a hospital operating theatre, fire fighting appliances, rescue vehicles, etc. In such cases the question of economics becomes of considerably less importance. It is common practice to make use of stand-by equipment or ancillary services in order to ensure instant availability of the emergency facilities. For example, operating threatres are provided with battery lighting. There is also widespread use of regular testing or inspection procedures, as in the case of 'first aid' fire extinguishers.

(d) Wise expenditure - To repair or replace?

An essential objective is the wise expenditure of money, time and effort, in other words the wise utilization of resources. The time will come with all equipment when consideration must be given to the relative merits of repair or replacement. Deterioration of certain parts of the equipment may be so advanced that repair would serve a very limited purpose and it might be wiser to invest rather more money in complete or partial replacement. Considerable work on replacement economics has been carried out in the Universities of many of the industrially developed countries. A proper understanding of the subject requires mathematical and statistical knowledge and the application of Operational Research techniques. It is by no means impossible, however, to reach approximately correct economic decisions with a combination of limited mathematical ability and simple common sense.

It is suggested that there are three main maintenance problems requiring a repair-or-replace decision:

(1) When parts of a large equipment fail. When is it worth having spare parts available to replace the defective parts, rather than carry out repair of the parts in situ?

(2) A complete piece of equipment fails. When is it better to replace it by new equipment rather than trying to repair it?

(3) Equipment is subject to gradual deterioration which incurs increasing running and maintenance costs. When should it be replaced? (This replacement need not necessarily coincide with a breakdown of the equipment).

It must be admitted that the decisions are not always based simply on economics. Expediency may play an important role in some circumstances. The situation of limited availability of currency for foreign spending has already been mentioned. Other factors of expediency may be the desirability to provide experience with certain kinds of work within the country, a national desire for self-sufficiency or the difficulty of obtaining imported spares quickly when required.

In considering the advantages which arise from the replacement of a complete item of equipment attention must be paid to the improved output which might result from a newer and more advanced type of equipment. If capital is available it is sometimes an attractive proposition to replace a piece of equipment even before it strictly requires replacement; higher production rates or better quality products might have considerable influence on the repair-or-replace decision.

(e) Reducing production costs

Good standards of maintenance will often reduce the cost of operating the equipment. Correct lubrication and adequate cleaning can, for example, make significant reductions in the power consumption. But it is the indirect savings which are of most significance; good maintenance can reduce the amount of sub-standard production. In precision engineering industries it has been found possible to link the quality control of the product with the standards of maintenance. If the quality of the product begins to deteriorate, immediate attention is paid to the condition of the machine producing it. Similar control can be exercized in the manufacture of chemicals, foodstuffs paper, and many other materials the quality of which can be influenced by the state of the equipment. With a universal demand for both greater productivity and productiv

quality, the profitability of an enterprise may be substantially influenced by its maintenance standards.

(f) Avoiding consequential damage

If a piece of equipment breaks down it may cost relatively little to repair - it is not only the cost of repairing it which must be considered. The breakdown of a relatively small component may start a chain reaction the cost of which could be out of all proportion to the original damage. An air receiver in which oil is allowed to accumulate may give rise to explosive conditions. If adequate inspection and maintenance is neglected there may indeed be an explosion. If that happens the cost of consequential damage to an adjacent air compressor, for example, might be much greater than the cost of replacing the air receiver.

(g) Keeping production safe

In human terms, the most important objective of maintenance - and one which must be complementary to any of the others - is that the plant or equipment shall operate safely. There are many ways in which lack of maintenance can lead to accidents, injury and loss of life. No excuse is offered for dealing in some detail with this objective.

Maintenance and safety are closely related from two distinct points of view. Firstly it must be accepted that the safety of all is often dependent on satisfactory standards of maintenance of equipment, of services, of floors, of stairs, etc. Secondly, maintenance personnel, by reason of their occupation, are more often in hazardous situations than anyone else; there is clearly need for careful training of maintenance personnel in safety practices.

The International Labour Organization is at present revising its Encyclopaedia of Occupational Health and Safety and one chapter is devoted to the maintenance of machinery and equipment. The following extracts serve to emphasize the safety/maintenance relationship:

Every production area will need maintenance treatment developed specifically for its need. It is only possible to generalize on the types of maintenance activity which should be considered. Every item of machinery should be examined thoroughly from the point of view of safety at least once a year. It will be clear that more frequent examination is needed in many cases.

Lubrication of moving parts is essential and the responsibility for lubrication should be clearly decided and made known. In some cases it will be convenient and expedient for the operator to apply the lubricant but in other cases the maintenance department should carry out the task. Lack of lubrication may result in friction, overheating and fire.

Most machinery becomes less potentially dangerous if kept clean. In addition to the general cleanliness of the machine it will be necessary to clean intake air filters, oil strainers and cooling water strainers. Failure to do this may result in overheating and fire. Mal-operation of mechanical parts may be caused by wear of surfaces in contact. Proper lubrication may in some cases be sufficient but sometimes it will be necessary to measure the amount of wear in components with a view to replacement before consequential damage can be caused. Many machines are now operated through clutch mechanisms and these, unless kept in working order, may transmit motion unexpectedly and so lead to operator injury. Lubrication, cleaning adjustment and checking for wear are all important. A brake is often an essential feature of a machine which works on an intermittent basis. It may have to stop the machine at a specific position and if it fails to do so there may be resultant injury.

One maintenance-caused accident occurred in a metallurgical shop where a ladle containing 250 kg of molten metal overturned because the key holding the gear wheel had slipped from its keyway. The ladle had received a routine examination only five days before; it was then lubricated and passed as being in good working order. A more thorough examination would probably have revealed wear on the key and on the keyway. It should be noted that better design would, in any case, have prevented the key from leaving its keyway; after the accident this was rectified by fitting a washer to the end of the shaft, thus closing the end of the keyway.

The prevention of accidents to persons operating machinery has, in most countries, been the subject of legislation especially in relating to the guarding of the machinery. It is not, of course, merely the provision of suitable guards which ensures the safety of the operators; the guards have to be maintained in good order. The mal-operation of an interlock guard on a power press can result in very considerable hazards. In circumstances such as these, where accuracy of adjustment is important, the regular inspection of the guard by a competent maintenance man is recommended. In some countries it is obligatory for an examination of power press guards to be made - and recorded - during each shift.

Regular inspection of all machinery should include checking that fixed guards over drives and other moving parts are securely in position. There is a tendency for parts of such fixed guarding to be removed by the operator for supposedly better access to the workpiece. It will be necessary for the

maintenance department and production supervision to work in close co-operation to keep this situation under control.

It is most important that the right type and degree of maintenance should be agreed and that it should then be regularly and efficiently carried out. If maintenance is not regularly and carefully done, then can arise a doubly dangerous situation as the machine operator may be lulled into a false sense of security.

Movement of parts in a machine - whether rotational or reciprocating - can result in vibration. In turn this can cause bolts and other threaded fasteners to become loose and eventually parts of the machine may become detached. Hazards like this will be mininized if regular maintenance inspection includes the checking of such items.

Some machines are difficult to guard if they are to be used. Wood-working machinery is possibly the best known example. The spindle speed of a high speed router may be as high as 24,000 rev/min and the teeth of a circular saw may be moving at a speed of 4,000 metres/min. The highest standards of maintenance of spindles, bearings and cutter mountings are essential.

There are also special maintenance needs for abrasive wheels used for grinding, polishing or cutting. Bearings and spindles must be kept in good condition but, in addition, care must be taken of the abrasive wheel and its mounting flanges. It is important that flange nuts are not tightened too much because damage to the wheel may result and it may fracture when running. It is also essential that a check should be made that the wheel runs true. There is a particular hazard which may arise with double ended grinders. These machines have one spindle end with a right hand thread and the other with a left hand thread; this is so that the wheel locking nuts tend to tighten in use. If, after dismantling for maintenance, the spindle is assembled incorrectly it may be found that the nuts slacken instead of tightening.

Many accidents to maintenance men are reported. Some are caused by lack of care by the men when working in hazardous situations. Too often maintenance men take unnecessary risks in the belief that they are saving time by inspecting or adjusting machinery in motion. Although this may sometimes be necessary, the hazards must be recognized. Training in correct practice must be given and appropriate tools and equipment provided.

Some of the most serious maintenance personnel accidents - often fatal - are caused by the lack of a safe system of work. Machinery is started with a maintenance man inside because another maintenance man or an operator is not aware of the first man's presence. There is particular danger with large machines and with machinery like conveyors which are not wholly in one part of a building.

There are two ways of ensuring safety. In the first, a 'permit to work' is issued by the responsible manager or supervisor after he has checked that the machinery is stopped, isolated, cleared of noxious fumes, cool and in all other respects safe to work on. Until the maintenance man returns the 'permit to work' the manager ensures that the machine is not started. As an alternative, or sometimes forming part of the first scheme, the maintenance man has his own padlock with one key. The master switch or control valve has provision for the attachment of the padlock to secure it in the safe position. The maintenance man then keeps the key with him until the task is completed. Where several men are involved, each will have his own lock and key and these will be attached to the switch or valve 'in parallel' so that all locks have to be removed before the machine can operate.

Other common types of maintenance accident include falls from inadequate access positions. This is doubly dangerous when men are working over moving machinery. Thought should be given to permanent platforms where frequent access is necessary, and to properly designed and constructed portable equipment for occasional use. It is important that maintenance equipment itself should be regularly examined. It is not unknown for this to be badly neglected.

Even when correct access equipment is provided and maintained, accidents can be caused by its misuse. Mobile scaffold towers are commonly used for many maintenance tasks at a height. They are high in comparison with their base width and they have a high centre of gravity. A man working at the top of such a tower is able to exert sufficient horizontal force to overturn the tower. Alternative recommendations are that the top of the tower should be tied, that the base should be weighted or that outriggers should be fixed to the base.

One of the most common type of injury to maintenance men is to the eyes. Goggles or other eye protection should be provided, proper instruction should be given and adequate supervision should be exercised especially when

the work involves grinding, welding or cutting, chipping and scaling.

Maintenance men are sometimes inclined to forget the potential dangers of electricity, steam, hot or greasy surfaces, toxic fumes, etc. Not only is initial safety training essential but a constant atmosphere of safety-awareness must be created. This is most important for maintenance personnel because of the varied nature of their work as well as because of its sometimes unavoidably hazardous character.

(h) Summarizing the objectives

If an attempt is made to produce a concise summary of the objectives of maintenance it results in the following:

> THE OBJECTIVE OF MAINTENANCE IS TO KEEP PLANT (ALSO EQUIPMENT, SERVICES, BUILDINGS AND ASSOCIATED FACILITIES) IN GOOD ORDER SO THAT IT MAY BE OPERATED SAFELY, ECONOMICALLY, AND AT THE APPROPRIATE PERFORMANCE STANDARDS FOR THE PERIOD IT IS REQUIRED FOR PRODUCTIVE USE. THE MAINTENANCE RESPONSIBILITY FOR ACHIEVING THESE ENDS MUST NECESSARILY ALSO EXTEND INTO THE SPECIFICATION, DESIGN, CONSTRUCTION, INSTALLATION AND COMMISSIONING STAGES. MAINTENANCE INTEREST AT THE DESIGN STAGE SHOULD BE DIRECTED TOWARDS ELIMINATING MAINTENANCE AS FAR AS IS ECONOMICALLY POSSIBLE - AND THEN AT FACILITATING THAT WHICH REMAINS.

PART 3: THE WIDER ASPECTS OF MAINTENANCE

(a) Design Considerations

Maintenance and repair are usually considered to be activities carried out once the plant has been commissioned and is in productive use. In many ways, however, the economical level of such activities is greatly affected by decisions made when the plant is designed or specified.

Indeed the - apparently paradoxical - first steps to better maintenance management lie in attempts to eliminate as much maintenance as is economically possible. The next steps concern making the 'inescapable' maintenance simpler by better access, etc., and only after those two sets of steps do improvements in the execution of maintenance demand attention. It may therefore appear that the sections which follow should logically have been placed first in this presentation. Indeed that is where the author believes they should be but he is also aware that the arguments for better execution of maintenance are likely to be those which have most immediate appeal to those relatively unfamiliar with the maintenance scene.

The elimination of unnecessary maintenance should be the aim of not only the designer and manufacturer of the plant or equipment, but also of the enterprise which is to use it, the financial controller, the production manager and maintenance manager. Some of the aspects of better design and selection will be technical, some will be financial but most will demand a balance of technical and economic advantages.

Perhaps the most easily recognized and therefore most widely used approach to design/maintenance improvement is the spending of additional money initially for higher standards of quality or reliability. In complex and rather exotic operations such as sending men to the moon the arguments for reliability are obvious. They can be meaningfully applied to more commercial activities such as under-ocean communication cables. In circumstances like these it is not the mere cost of the failed component which must be considered - this might be quite insignificant. For example, the failure of a component costing only a few dollars in part of a transatlantic cable service could conceivably lead to a repair cost of £500,000 since it would be necessary to send a cable ship to locate the fault under several miles of ocean before rectifying it and returning the cable to position. In addition there would be a high loss of income whilst the facility was out of service.

Ordinary manufacturing or process plants are perhaps unlikely to show quite such differentials between the cost of the component and the total maintenance cost (direct + indirect maintenance costs) consequent upon failure. Nevertheless it is always worth while considering the advisability of spending money initially to save money - possibly repeatedly - on maintenance. In the process industries stainless steels and other materials with corrosion-resistant properties can in many cases be justified. Better quality materials for bearings have reduced maintenance costs in many types of rotating machinery. Materials with wear-resistant properties have successfully reduced maintenance costs in equipment where abrasive ingredients or products are handled.

It must not be supposed that the interests of better maintenance will always best be served by taking a specific item of equipment and spending time, money and effort in improving its design. A much more fundamental approach should be adopted which calls for the disciplined thought of the method study engineer. The question should first be asked 'Is this the best way of doing the job?'. It might be that a completely different piece of equipment would provide a better solution to the problem - it might perform better and require less maintenance. It might cost more money or it might even cost less. But the overall economic argument can be quantified.

A warning must also be given against thinking of items in isolation. Very often a much broader approach to cost effectiveness in design and maintenance is necessary. Component reliability provides a good example. Reilability costs money. This is not surprising when it is remembered that the IEC (International Electrotechnical Commission) definition of reliability is 'The characteristic of an item expressed by the probability that it will perform a required function under stated conditions for a stated period of time'. Clearly higher reliability calls for closer tolerances in manufacture as well as for closer control of the quality of the materials used.

It is therefore not economically attractive to call for more reliability than is really necessary. For many types of equipment it is reasonable to suppose that a component with 96% reliability might cost ten times as much as one with 90% reliability. Even if the system design demands the higher unit reliability the 'broad view' approach could save money - two 90% reliable components in tandem will provide rather more than the required 96% reliability for only twice the cost.

There is a very strong argument for limiting the number of components (other than those in tandem as above) in a piece of equipment if an acceptable degree of equipment reliability is to be obtained at a realistic cost. For example: An equipment with one hundred components each with a reliability of 99% would have an overall equipment reliability of 36%. But an equipment with four hundred components would have an overall equipment reliability of only 3%.

Simplicity is obviously desirable as a design factor leading to better maintenance. It is desirable not only because of the cost of reliability but also because of the additional complexity of fault diagnosis. To some extent improvements in diagnostic techniques have kept pace with the growing complexity of equipment but the generalization of 'the simpler, the better' is strongly advocated.

It is clear that design considerations of maintenance do not have to result in higher initial expenditure. Careful thought may lead to greater simplicity in design as well as to better selection of standard materials or components. The adoption of standard widely-available components instead of specially-produced ones will reduce the cost of the replacement parts and will also help to avoid the delays in obtaining special parts.

There should be greater standardization of items in common use such as fasteners, driving belts, lubricants, etc. This will reduce the number of items in the maintenance stores and so reduce costs. It will also cut 'delay' costs.

Some equipment manufacturers are not as helpful as they could be in providing maintenance recommendations, parts lists, etc. Some are not very co-operative about supplying replacement parts. There is, however, a growing realization amongst manufacturers that the service they provide in these respects will increasingly influence decisions about placing future orders for their equipment. Maintenance managers should be - and indeed are - concerned as much with the initial specification of the equipment as with its eventual maintenance.

It is fashionable to blame equipment designers and manufacturers for the unnecessary maintenance which results from lack of thought. It is right that they should accept the main responsibility for such shortcomings. But far too infrequently do maintenance managers do as much as they could to improve the situation. There is, throughout the world, too little feed-back of information based on practical maintenance experience. An item of equipment is found difficult to maintain, perhaps because access is awkward. Rarely does the maintenance manager complain to the manufacturer; it is often argued that the manufacturer would not be interested. Maintenance managers would perform a very valuable service and make a significant contribution to design improvement if they would conscientiously provide such a feed-back of maintenance experience. It is certain that the more perceptive manufacturers would welcome it.

(b) The importance of design/maintenance co-operation

In considering the design/maintenance interface it has seemed right to concentrate first on the influence which the designer can have on maintenance - and also on the influence which the maintenance manager can have on future design. There is, however, a slightly different aspect of the subject which is equally important. It has been inherent in what has already been said but it deserves specific mention.

The maintenance manager should adopt the 'critical appraisal' approach, borrowed from method study, when dealing with an actual maintenance operation. Indeed, if he does not do this he might well be concentrating his efforts on carrying out a particular task more and more efficiently when, in fact, the task might not be the right one. It might not, in some circumstances, be necessary at all. It has been said that the cheapest maintenance is that which is not done at all - and that the main objective of the maintenance manager should really be to do as little maintenance as possible, consistent with the other

objective of keeping the plant available for use!

Two examples are drawn from maintenance manangement training seminars to illustrate the thought processes in designing out unnecessary maintenance.
(1) At the entrance to a large workshop the doorway is flanked on one side by the foreman's office and on the other by a brick wall which protects a storage tank. The maintenance problem is that the wall frequently becomes damaged by trucks negotiating the rather narrow approach to the doorway. What should be done? In attempting answers from the basis of good maintenance technology suggestions can be made for fixing steel plates to the wall, painting guide lines on the floor, providing a raised kerb alongside the wall, and so on. But in practise the astute maintenance manager would ask 'What is in the storage tank?' In the case reported the tank had in fact been out of use for two years. The wall was protecting an unnecessary tank and an unnecessary maintenance task was being suggested as a result.
(2) The maintenance problem is that it takes two hours every week to re-pack the glands of a pump. The pump is used to transfer a sugar solution from a ground-level tank (into which it is delivered by a road tanker) to a high level storage tank before it is used in some food manufacturing process. There is a great temptation to start with the obvious engineering-based answer - improve the method of packing the gland. But this should really be the action taken finally if all other solutions fail. Indeed the first question to be asked is whether the pump is required at all. Would it not be possible for the road tanker to deliver the sugar solution direct into the high level tank? If this is not possible the second line of attack on the overall problem is to consider whether a different type of pump - possibly one without a gland - could prove economically attractive.

When such examples are offered it might be expected that the existence of similarly 'obvious' cases for eliminating maintenance would be queried. Yet even very experienced maintenance managers will admit that a deliberate exercize of this kind could be more profitable than almost any other expenditure of time. It does not, however, form part of the daily tasks of many of them.

The practising maintenance manager should so discipline himself that a substantial part of his time is spent on looking objectively at the situation. He should constantly say to himself 'Can that maintenance task be eliminated? if not can it be simplified? Only if he is doing this can the maintenance manager be fulfilling his true function. He will, of course, need to establish proper supervisory control of the maintenance staff.

Although this is not usually a problem which should present great difficulties, it is one for which there is no universal answer.

(c) The effectiveness of maintenance

The cost of carrying out maintenance work can vary greatly according to the effectiveness of the organization, management and supervision of the maintenance department. It is not unusual to find that the person responsible for an extensive maintenance department is a very experienced engineer with all the necessary technological qualifications and yet with little or no formal management training. Some surveys have revealed that maintenance department deficiencies have arisen from poor management decisions rather than from any specific lack of engineering expertise. The developing countries already have the opportunity of remedying this situation. The United Nations (I.L.O) Management Centre at Turin in Italy offers a course every year for qualified engineers who require additional training in maintenance management techniques. The course lasts for almost three months and requires fluency in English, French or Spanish. For those who cannot be spared for such a period there is an interesting pilot scheme in the United Kingdom; this is for a maintenance management diploma and it requires attendance at a college for three two-week periods in the first year and for three six-week periods spread over the next two years. It is hoped that other countries might consider similar courses. (The author would be pleased to pass on information to appropriate bodies).

Effectiveness of maintenance is also influenced by the general status of the maintenance staff. For many years maintenance personnel were considered to be less important to the enterprise than those operating the plant. With greater mechanization and automation the maintenance staff is becoming almost daily more important. Better educational and training facilities are being provided for all grades of maintenance staff.

Once maintenance work is accepted as being of importance to a nation's economy, it achieves social acceptability and its considered to be a worthwhile job. Experience shows, however, that it is not unusual for production workers, often in jobs requiring a lower level of skills, to receive higher payment than maintenance personnel. In some countries it has been found necessary to pay particular attention to maintenance wage rates in order to attract the calibre of worker required for a demanding job.

(d) Why is maintenance neglected?

When the United Nations Centre for Industrial Development set up its expert group on repairs and maintenance in 1966 an examination was made of the maintenance situation in industrially developing nations. It was found that - in common with many of the industrially developed countries - there was often management indifference to (or unawareness of) the benefits of better standards of maintenance. It was seen that lack of maintenance often involved developing countries in high capital expenditure which they could ill afford.

It was found that a shortage of suitably skilled personnel made better maintenance standards difficult to achieve. There was seen to be unsufficient practical training in many of the vocational schools; what training was available often took place on equipment which was outdated. Another major obstacle to better maintenance was the shortage of readily available replacement parts. Although local industries could frequently produce a substitute part, the quality, durability, accuracy and surface finish would often fall below the minimum practical standard. Four years later this situation is improving but there are still difficulties of providing all the necessary replacement parts.

Strong views were expressed by the industrially developing countries that equipment should be of simple robust construction with as little 'gadgetry' as possible. Equipment had to withstand overloads imposed by over zealous and sometimes inexperienced operators. Climatic conditions also tended to produce problems and equipment generally must be designed to suit the operating conditions.

No-one will claim that sufficient improvement has been made. The problem is made more difficult by the fact that maintenance is, in many ways, not an exact science. Local judgement, often subjective judgement, is involved. It is certainly possible and highly desirable to apply better scientific principles to the art of decision-making in maintenance management but common-sense will continue to be a vital factor. Above all, efforts must be made to bring an improved sense of maintenance awareness to those responsible for the direction of enterprises of all kinds. There is an urgent need for the determination of incentives at a national level for better standards of maintenance; this is a largely unexplored field.

It must be emphasized that the subject of 'maintenance and repairs' means more than just putting things right when they have gone wrong. There is always likely to be a need for purely remedial work, and in some circumstances a large part of the 'maintenance and repairs' load may properly fall into this area. In other circumstances it will be right to spend more time and money in

designing out the need for maintenance and in carrying out preventive maintenance. No universal answer can exist to the determination of the correct balance of maintenance and repairs activity - each set of circumstances must be considered on its own merits.

The significance of maintenance is the service it offers to production. The objectives of maintenance are often mainly guided by economic factors, sometimes by expediency and always by considerations of safety.

In the industrially developed countries it is widely accepted that industrial productivity must be improved. All countries have different problems, social, political and economic, but clearly the challenge of a growing world population and the international desire for peace must lead us to thoughts of improving industrial productivity on an international scale. Maintenance has a part to play.

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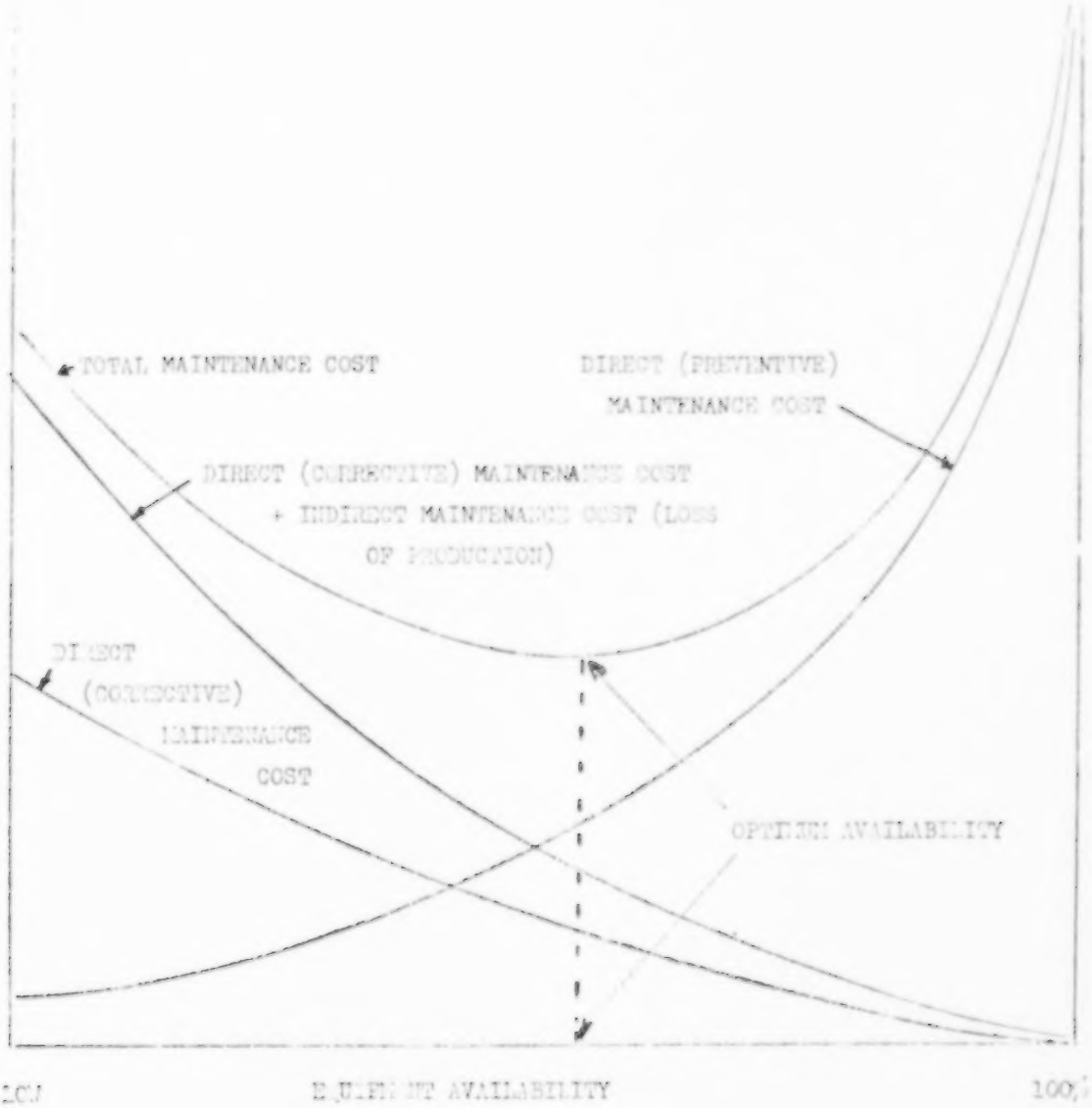
Dennis Parkes Bibliographical references.


TOTAL MAINTENANCE COST
DIRECT (PREVENTIVE) MAINTENANCE COST
DIRECT (CORRECTIVE) MAINTENANCE COST + INDIRECT MAINTENANCE COST (LOSS OF PRODUCTION)
DIRECT (CORRECTIVE) MAINTENANCE COST
OPTIMUM AVAILABILITY
COST
EQUIPMENT AVAILABILITY
100%